BRIEFING PACKAGE
FOR
GAS-FIRED WATER HEATER IGNITION
OF
FLAMMABLE VAPORS

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NOTE: This document has not been reviewed or accepted by the Commission.
Initial HK **Date** 12/29/94

CPSA 6 (b)(1) Cleared
X No Trivial or Frivolous or Product Identified
11/29/94

Executive Summary

This memorandum provides updated information to the Commission to assist in choosing options to reduce the risk of death and injuries associated with gas-fired water heaters igniting flammable vapors. Traditionally designed gas-fired water heaters draw combustion air through the bottom of the appliance. In the event of a gasoline or other flammable liquid spill, vapors, which are heavier than air and tend to layer near the floor, are susceptible to being drawn into the water heater and ignited.

Gas-fired water heaters igniting flammable vapors cause an estimated 1,961 fires each year, resulting in an estimated 316 injuries, 17 deaths, and $26 million in property damage for a total societal cost which may be as high as $395 million. Typically, injuries occur when the victim is using flammable liquids (usually gasoline) for cleaning purposes, or when the liquid leaks or is accidentally spilled near the water heater.

On June 23,.1994, the Commission was briefed on this issue. Subsequent to the briefing, the Commission learned about additional industry activities to reduce the hazard and directed staff to reexamine completed industry research, to evaluate ongoing and planned industry activities to address the hazard, and to brief the Commission on its findings.

The material made available by industry has been reviewed. Industry is testing a new technology to eliminate the hazard. Preliminary results are promising, but additional testing is needed. An industry-sponsored standards development program to develop performance requirements to protect against ignition of flammable vapors has begun. The CPSC staff has reservations about the technical approach proposed and expressed its concerns to the Technical Advisory Group overseeing this project at its October 27, 1994, meeting. Industry is receptive to our concerns and is examining a "worst case" scenario as a basis for the test method.

A reexamination of completed industry research supports the staff's conclusion that raising water heaters 18" can significantly reduce the risk of vapor ignition.

CPSC staff's position is that the only adequate way to address the hazard is through a performance standard that leads to water heater design modification. Currently, industry estimates 39 months from the start of standards development to the effective date of a voluntary standard. Staff believes it may be possible to accelerate the voluntary standards process (particularly if ongoing research is successful).

Options available to the Commission to address this hazard include:

1. Issue an advance notice of proposed rulemaking to develop a performance standard to reduce or eliminate the risk of death or injury from ignition of flammable vapors.

2. Not issue an ANPR and work with industry to develop a voluntary standard.

Staff recommends option 2, that the Commission not issue an ANPR and work with industry to develop a voluntary standard. Industry has addressed the reasons for the previous recommendation to publish an advance notice of proposed rulemaking. At the November 22, 1994, industry meeting with Chairman Brown, industry stated that they are committed to developing a performance standard for new gas-fired water heaters to address the risk of death and injury from the ignition of flammable vapors. Industry is also is evaluating a new burner design to eliminate the ignition hazard.

If the Commission chooses this option, staff will alert the Commission immediately if progress on developing the performance standard is unsatisfactory and will brief the Commission on options to address the problem. This would include the option of issuing an ANPR, and initiation of the test method development work necessary to support rulemaking.

TABLE OF CONTENTS

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: NOV 29 1994

TO : The Commission
: Sadye E. Dunn, Secretary

Through : Eric A. Rubel, General Counsel EAR
: Bert Cottine, Executive Director

FROM : Ronald L. Medford, Assistant Executive Director RLM
for Hazard Identification and Reduction
: Donald W. Switzer, Project Manager for Fire/Gas Codes and Standards, ESEE (504-0508 ext. 1303) DWS

SUBJECT : Briefing Package for Gas-Fired Water Heater Ignition of Flammable Vapors

Purpose : To provide the Commission with the latest information on industry activities to address the hazard posed by gas-fired water heaters igniting flammable vapors

1 Background:

On June 23, 1994, the Commission was briefed on the Options Package for Gas-Fired Water Heaters and Ignition of Flammable Vapors (TAB A). At that time, as reported in the Options Paper, "The staff's greatest concern is an apparent unwillingness on the part of the water heater manufacturers to take a serious look at the potential deficiencies (of taking combustion air from near the floor) in the current design of water heaters." That concern was based primarily on:

1. Industry's insistence that the problem is not a water heater issue, but rather a consumer behavior issue that should be addressed solely through a consumer education program,

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2. Industry's lack of progress in developing a performance standard to address this issue, and

3. Test conditions and reported results from industry-sponsored research which appear, to CPSC staff, to minimize the effectiveness of elevating water heaters to address the flammable vapor ignition hazard.

On June 27, 1994, C. Reuben Autery, President of the Gas Appliance Manufacturers Association (GAMA), sent a letter to Chairman Ann Brown (TAB B) expressing concern about the June 23, 1994, briefing. In that letter, GAMA protested that the Options Paper and briefing did not provide the Commission with accurate information on the status of industry efforts to address the flammable vapor ignition hazard, and "shows an unreasonable bias on the part of the Commission staff." GAMA's primary concerns were that staff 1) disparaged the significance of industry-sponsored research into this area, and 2) did not provide information on ongoing standards development activities. The Commission staff responded to these concerns in a memo to Ronald L. Medford, Assistant Executive Director for Hazard Identification and Reduction (TAB C).

Based on the availability of additional information that GAMA identified in their letter, the Commission cancelled the decision meeting scheduled for June 30, 1994, and directed staff to:

1. Evaluate ongoing and planned industry efforts to address the flammable vapor ignition hazard,

2. Reexamine previously completed industry research, and

3. Brief the Commission on staff findings as soon as possible.

On July 7, 1994, staff requested industry to provide test protocols, schedules, and draft and final reports of studies and tests in order that staff could evaluate industry efforts to address vapor ignition (TAB D). GAMA provided preliminary information immediately, followed shortly by a more detailed response (TAB E and TAB F). Staff reviewed the material provided, requested additional information, and held a meeting to discuss the issues presented in the GAMA material (TAB G and TAB H). The material provided by GAMA and information provided at the subsequent meetings are the basis for the following discussion of the status of industry activities to address water heater ignition of flammable vapors. GAMA provided written response to our questions after the meeting (TAB I).

2 Evaluation of Recent Industry Activities:

Industry has initiated three activities to address the flammable vapor ignition issue. The first industry activity is testing of a new design that may reduce the potential for flammable vapor ignition. The second is a program to develop a test methodology to evaluate water heater designs for resistance to flammable vapor ignition. The third project is recently

completed "live fire" testing of the efficacy of a 14" sheet metal barrier in reducing flammable vapor ignition.

2.1 Design Testing:

Industry is currently testing prototypes of water heaters incorporating a new burner design to determine its potential to reduce the hazard of water heaters igniting flammable vapors. In traditionally designed water heaters, there are two sources of combustion air. Primary combustion air is mixed with the fuel before the fuel enters the burner. Primary combustion air can therefore be thought of as part of the fuel mixture. Secondary combustion air is drawn into the combustion chamber through holes in the bottom of the water heater combustion chamber. Secondary air then burns with the fuel after the fuel mixture is ignited. This means of providing secondary air is the path by which flammable vapors can enter the combustion chamber of traditionally designed water heaters. Flammable vapors in the vicinity of the appliance are drawn into the combustion chamber with the secondary air, are ignited by the main burner or pilot burner, and then flash back out of the holes in the bottom of the combustion chamber and ignite the vapors in the room. The resulting flash fire expands very quickly, and has resulted in a number of deaths and serious injuries.

The innovative burner design that industry is currently testing does not use secondary air. This allows the bottom of the combustion chamber to be sealed, precluding ignition of any flammable vapors that surround the water heater. Preliminary test results are favorable, but significant additional testing will be needed prior to commitment to production. Industry representatives have assured staff that they are committed to continuing the test program until the new burner design is proved to be either successful or ineffective in eliminating the vapor ignition problem, without introducing other unforeseen safety hazards. It is premature at this time to estimate if and when products using the new technology could be available.

It must be emphasized that although the new burner design has been patented, it is an unproven technology. It was developed for another application and has not been used in water heaters. Before this technology can be accepted for this use, it must correct the vapor ignition problem and it must satisfy all current safety and efficiency requirements without causing other, currently unforeseen, hazards. This is the purpose of the ongoing industry test program.

2.2 Test Method Development Activities:

GAMA provided CPSC with a copy of a proposal made by Arthur D. Little, Inc., (ADL) to the Gas Research Institute (GRI) for development of a test methodology to screen water heater designs for resistance to flammable vapor ignition. The proposal is dated February 1994. Work began in October 1994. GAMA states that this delay is because of difficulties regarding liability. Staff understands that the work will result in a test method that

would be included in the American National Standards Institute (ANSI) Standard for Gas-Fired Water Heaters, ANSI Z21.10.1. This is the standard to which essentially all gas-fired water heaters are currently certified.

The standards development program described by the ADL proposal is a multi-task effort that intends to establish a standard set of test conditions to mimic conditions in the field and to test water heaters under those conditions. Those water heaters that cause ignition under the test conditions would fail the test and not receive design certification. GRI, which is providing funding for the method development, has established a Technical Advisory Group (TAG) to review the process and results of this project. The TAG consists of representatives from the gas industry, manufacturers, and industry trade associations, and CPSC staff. ADL estimates it will take 39 weeks from contract award (October 1, 1994) to complete development of the test method. GAMA estimates that it will take an additional 30 months from completion of the test method for an ANSI standard to become effective.

The CPSC engineering staff was concerned that ADL's originally proposed test method development program might not produce a test method to reliably evaluate water heaters' resistance to igniting flammable vapors when installed in the home. ADL intended to establish a "typical" accident scenario and develop their test method around a set of conditions that may or may not exist in an actual home. This could result in an appliance passing the test method, but being susceptible to igniting vapors in a home where the conditions do not match the test conditions.

What is needed is a quick way to ascertain whether a water heater will ignite flammable vapors when they are present. At the October 27, 1994, TAG meeting CPSC staff explained that it is examining a more direct way to measure water heater resistance to flammable vapor ignition. The staff's preliminary concept is to use a two-gas non-flammable tracer system to simulate the expected conditions. Two gases would be injected into the test room containing the operating water heater. One tracer gas, having a molecular weight close to that of air, would be used to measure the amount of room air drawn into the water heater. The other tracer gas, having a molecular weight similar to that of the flammable vapors, would be injected into the room in a manner simulating worst case generation and spread of gasoline vapors. The second tracer gas would be an indicator of the flammable vapors that have passed through the flame front. The tracer concentrations would be measured using electron capture gas chromatographic techniques. The room would be constructed so that the natural circulation as well as any other flows could be produced. The natural air flows could be accomplished by heating or cooling the ceiling or floor and by operating the water heater. Precision DC fans would be used for other required air flows that must be artificially generated. Criteria for vapor ignition would be established, and these criteria would be verified by "live fire" test to demonstrate the validity of the methodology. It is possible that a water heater could fail to meet the criteria of this proposed tracer gas test. In this case, it could be possible to qualify the design through rigorous live fire testing using the same test conditions as established with the tracer system.

CPSC staff met with GRI and ADL on November 15, 1994, to discuss our concerns in detail and explore ways to resolve them. In response to our concerns, GRI and ADL agreed

to explore a test method in which a water heater could not ignite vapors when installed in a chamber completely filled flammable vapors. This approach appears to meet all of the staff's concerns.

2.3 Barrier Effectiveness Tests:

In June 1994, the American Gas Association Laboratory (AGAL) in Cleveland, Ohio conducted two "live fire" experiments (TAB E) to determine the effectiveness of a sheet metal barrier in reducing gas-fired water heater ignition of flammable vapors. The testing was initiated in response to CPSC testing which showed that a sheet metal barrier may inhibit flammable vapors ignition by causing the appliance to draw combustion air from 14" above the floor.

Because of safety considerations, the testing by the CPSC Engineering Sciences Laboratories was not "live fire" testing. Staff simulated appliance operation and measured the concentration of gasoline vapors in the combustion chamber to determine if ignition would have occurred. As reported in the June 8, 1994, Options Paper, "The results were that the barrier provided significant protection against flammable vapor ignition."

The two AGAL experiments involved installing a typical gas-fired water heater in a room measuring 6'x10'x8'. A sheet metal barrier 14" tall was placed around the appliance about 2" from the water heater shell. In Test 1, the barrier was sealed to the floor with tape. In Test 2, the barrier was sealed to the floor with silicone caulking. A gasoline spill was created by tipping a full one-gallon gasoline can 20 " from the barrier. Approximately 0.75 gallon was spilled from the can toward the water heater. Movement in the room was to be initiated 1 minute after main burner ignition by moving a plywood mannequin at approximately 3 feet per second on a three-foot track toward the water heater and terminating about two feet from the appliance.

In Test 1, ignition occurred 27 seconds after the gas was spilled. The pilot burner ignited the spill before the main burner was lit. AGAL speculates that rapid ignition was the result of liquid gasoline passing through the tape and running under the water heater. There was no mannequin movement because vapor ignition occurred before main burner ignition.

In Test 2, the main burner lit 2 minutes and 25 seconds after the spill. Vapors ignited 3 minutes and 55 seconds after the spill. There were two movements of the mannequin prior to ignition. When staff reviewed the video tape of this test it appeared that ignition started at the top of the barrier at the rear of the water heater opposite from the spill.

The results of this very limited testing appear to contradict the results of the CPSC testing. However, since only two tests were performed, staff is very cautious in interpreting the results. As discussed in the June 23, 1994, briefing , live fire testing needs to be done to

to explore a test method in which a water heater could not ignite vapors when installed in a chamber completely filled flammable vapors. This approach appears to meet all of the staff's concerns.

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confirm the utility of installing a barrier as a means to prevent flammable vapor ignitions. While there are a number of possible explanations for the variation between the two sets of results, it would be speculative to try to explain the cause of the different results based on the limited data on hand.

3 Evaluation of Previous Industry Research:

Arthur D. Little, Inc., under contract to GAMA, conducted research "to investigate and characterize hazards associated with the ignition of flammable vapors by residential gas water heaters in the United States." The investigation consisted of two tasks: Data Collection and Analysis (Task 1), and Analytical Modeling and Experimental Testing (Task 2). In Task 1, ADL examined incident data and attempted to develop accident scenarios to account for various types of accidents. In Task 2, ADL tested gas-fired water heaters under a variety of conditions. ADL states "The overall goal of the project is to develop a comprehensive understanding of the extent of the hazards identified and the effectiveness of current mitigating measures. " CPSC asked GAMA: "Is this work viewed by GAMA as suitable for development of a standard test method?" GAMA responded (TAB F), "...Phase I was not intended to investigate solutions in any comprehensive way or to establish a statistically valid protocol to assess design options or other means to reduce the ignition hazard. The latter goal is the intent of the GRI sponsored work just beginning."

3.1 Flammable Vapors Hazards Ignition Study, Task 1

As stated above, the purpose of ADL's Task 1 was to collect, review, and analyze data on fires involving water heater ignition of flammable vapors. The data were then grouped according to the conditions of the accident to generate accident scenarios that could form the basis of a subsequent test program (Task 2). ADL examined 142 reports (103 CPSC Epidemiological Investigation Reports, and 39 National Fire Protection Association reports) to generate seven accident scenarios.

The Directorate for Epidemiology has reviewed the Task 1 report and points out some significant shortcomings in the scenarios developed in Task 1 (TAB J), in particular

1. The ADL scenarios are not representative of the National Fire Incident Reporting System (NFIRS) data.

2. The scenarios were more severe than indicated in the NFIRS data.

Since the scenarios formed the framework for ADL's Task 2 testing, the results of the testing may not be representative of what is occurring in the field. For example, in about half of the incidents, the source of gasoline is a leak, typically from either a lawn mower or a weed trimmer. The gas tanks on these appliances are smaller than the amount of gasoline spilled in many of the experiments in Task 2. Using more gasoline in the tests increased the likelihood of vapor ignition, and may explain why Task 2 results appear to conflict with field reports

indicating that elevating water heaters reduces the hazard of flammable vapor ignition.

3.2 Flammable Vapor Hazards Ignition Study, Task 2

The two stated primary goals of Task 2 were "to understand, through experiments, the dispersion of flammable vapor under controlled conditions and to determine the role of the water heater as an ignition source." Staff is concerned that many of the conditions chosen for the testing were not representative of field conditions. Also, staff disagrees with ADL's interpretation of the results.

ADL performed a total of 37 "live fire" tests to gain information on the role of water heaters as ignition sources for gasoline vapors. There were a total of seven primary variables in the test matrix; water heater height, room size, size of spill, room temperature, floor temperature, distance to spill, and movement in the room. A brief discussion of CPSC staff concerns with the test conditions follows.

3.2.1 Test Conditions

The staff has concerns that the test conditions chosen for ADL's Task 2 testing were more severe than typical home conditions, which may have caused more vapor ignitions under the test conditions than would be expected in the home. This could minimize the apparent effectiveness of elevating water heaters to prevent flammable vapor ignition. (For the purpose of increasing the safety of new water heaters, however, a test method with severe conditions is desirable.)

Room and Floor Temperature

ES disagrees with the floor and room temperatures chosen for the tests. When originally published (and provided to Commission staff), the Task 2 report showed a total of 13 experiments where the floor temperature in the test room exceeded the air temperature in the room. Subsequent to report distribution, numbers in the data tables were found to be transposed. In November, 1993, the data tables were corrected and the final number of cases where floor temperature exceeded room temperature was revised downward to 6. CPSC received copies of the revised tables with the submission of additional data requested from GAMA. We remain concerned that elevated floor temperatures increased the amount of vaporization of the gasoline spill on the floor, making vapor ignition more likely than may be the case in the typical accident scenario of which we are aware. ADL maintains the intent of those test conditions was not to increase vaporization, and that they were trying to mimic conditions in carports in the summer in the southwest, where many of the accidents occur. However, the tests were run in a tightly sealed room with an estimated air exchange rate much less than expected for a typical carport scenario, resulting in higher vapor concentrations and greater likelihood of ignition .

In subsequent conversations, industry personnel explained that the variation between room and floor temperature was also a product of the of the test facility (TAB H). The tests

were done in a room constructed outside on a cement slab during the winter. The slab was heated to above outdoor temperature of early spring in Cleveland, OH. The room itself was heated with an industrial space heater which had to be turned off prior to spilling the gasoline. This caused the room temperature to fall rapidly, resulting in average room temperatures below the floor temperature. This could result in an apparent decrease in effectiveness of raising the water heater.

Spill Size

As mentioned in the Task 1 discussion, we are concerned about the amount of gasoline used to produce the spills. When CPSC staff examined the accident reports, it determined that about half of the incidents involved gasoline leaking or spilled from the gas tanks of power tools such as lawn mowers and weed trimmers. Of the 32 spill tests performed by ADL, 18 tests were run with 1 gallon spilled, 7 with 2 gallons, 3 with 1.5 gallons, and 4 with a 0.5 gallon spill (4 tests were run with gasoline-soaked rags as the source of vapors). Staff believes that these spill sizes do not reflect field conditions and would tend to minimize the effectiveness of raising the water heater.

Motion in the Room

Motion is a critical variable, since gasoline vapors are heavier than air and tend to stay near the floor. Motion in the room effectively stirs the room air, lifting the vapors above the level they would achieve in a static room with no air currents. By controlling the amount of mixing, the likelihood of ignition can be influenced. ADL used a plywood cutout of a 3-foot tall figure in the shape of a person. Motion was generated by pushing and pulling the dummy back and forth a rate of approximately 2 feet per second over a distance of 2 feet. The dummy moved on tracks that were directed at the water heater. In both the 6'x10' and 8'x8' rooms the track was directed at the water heater and approached to 19" from the water heater. Staff believes that using a flat cutout and moving it at this rate may create excessive air movement in the room, thereby increasing likelihood of ignition.

3.2.2 Interpretation of Results

As a result of the Task 2 program, ADL offered general observations and insights into water heater ignition of flammable vapors:

- "Motion is an extremely important enhancement of ignition.... In an extremely quiescent environment with no temperature gradient, diffusion vertically will occur very slowly.....However, movement of some nature is almost always present.....This motion will elevate the vapor level and promote mixing. Ignition when mixture (sic) reaches an ignition source with a flammable vapor concentration above the flammable limit."

- "In comparison to floor mounted tests, elevation of the water heater delayed ignition in some cases but always resulted in a large volume of flammable vapor being present when ignition occurred. These events were characterized by

ignition more like explosions than pool fires."

- "Results of our tests were sensitive to spill volume and room size. The latter (sic) is perhaps obvious since greater spill volume gave larger spill areas, more surface for evaporation, and more liquid to evaporate. Room size is also important, particularly during our tests with minimal ventilation, introduced only near the ceiling. Natural vapor build-up and effect of motion are enhanced in smaller volume rooms."

- "....Our conclusion is that temperature is not as important as motion, room size, or spill volume."

As stated earlier, CPSC staff met with ADL staff on December 16-17, 1993, to review the Task 2 study (TAB K). At the time of the meeting, the results had been published for approximately 6 months, and amended tables had been supplied to GAMA. In the Task 2 report, ADL reached the following general conclusions:

"As a result of these tests, we [A.D. Little] have several general conclusions:

- A gasoline spill near a floor mounted water heater is likely to result in ignition of flammable vapor.
- Rags soaked in gasoline in small rooms can present ignition sources.
- Repeated tests are required to validate conclusions due to the variability and uncertainty associated with tests of this nature.
- An 18-inch stand will delay but not eliminate ignition of flammable vapors, particularly in realistic situations where movement is present. The delayed ignition can produce significant pressure waves."

Based on a preliminary analysis of the published results, and the December, 1993, meeting, J.L. Mulligan of CPSC's Engineering Laboratories concluded, in part, that "...Raising the water heater 18 inches appears to significantly reduce the likelihood of ignition in case of a gasoline spill." (TAB K)

3.2.3 Analysis of Industry Data

A follow-up engineering analysis of the Task 2 results was done to determine the effects of raising the water heater and varying the test conditions (TAB L). Because of the small number of tests compared to the large number of variables, and because multiple variables were changed for many of the tests, a statistical analysis could not be performed. ES therefore took a "common sense" approach and grouped sets of tests of raised and unraised water heaters where few variables changed.

Analysis was done on data contained in tables 8-10, pages 20-22, of the Task 1 report. Tables 8-10 presented results of 32 "live-fire" gasoline spill tests. The effect that eight variable parameters had on ignition time of gasoline vapors by a water heater was examined. The eight parameters were: elevation, movement, floor temperature, room temperature, effect of

having floor temperature greater than room temperature, room size, amount of spill, and spill distance.

The method used to examine the data was simple and straightforward. By grouping together tests in which 7 of the 8 variables were held essentially constant it was possible to "isolate" the eighth variable such that its effects on ignition time could be better understood. The results are summarized as follows:

- Elevating a water heater 18 inches generally increased the time to ignition and prevented ignition when similar elevated and unelevated cases are compared.
- Movement in the room reduced the time to ignition.
- Increasing floor temperature slightly reduced the time to ignition.
- Increasing the room temperature slightly reduced the time to ignition.
- Having the floor temperature greater than the room temperature slightly reduced the time to ignition.
- Increasing the room size increased the time to ignition.
- The greater the amount of the spill, the greater the reduction in the time to ignition.
- Increasing spill distance increased time to ignition.

4 Economic Considerations

There are several possible approaches to reduce this hazard by modifying the design of water heaters currently on the market without the cost of designing entirely new water heaters. Direct vent water heaters and appliances currently on the market that take combustion air from above floor level may hold promise as solutions.

Direct vent water heaters use an annular vent pipe to both exhaust the flue products and bring combustion air from outside the dwelling where the appliance is installed. Combustion air is brought in through the outer portion of the annulus, and combustion products exit through the inner portion. The success of this approach depends on keeping the flammable vapors out of the appliance combustion chamber. This requires that the combustion chamber and the air intakes be sufficiently tight to prevent the vapor concentration from reaching the LEL in the combustion chamber when a flammable mixture exists in the vicinity of the appliance. As this is not currently required, staff believes that current designs may need to be modified for this application. A direct vent water heater normally is vented horizontally thorough the wall to the outside. This design holds promise only for installations where a direct vent appliance can be installed. In those installations where it is not possible to vent the product horizontally, the air intake portion of the vent annulus could be opened above the water heater. This would result in combustion air being taken from above the water heater, greatly reducing, but not absolutely eliminating, the potential for flammable vapor ignition. At the current time direct vent water heaters are significantly more expensive than typical residential water heaters. The Directorate for Economics Analysis reports that the cost differential is about $200.

At least one manufacturer lists a water heater in their catalogue that takes combustion air from above the floor by perforating the outer appliance jacket, and ducting the combustion air down between the inner tank and the outer jacket. It may be possible to modify this design by raising the intake holes and sealing the combustion chamber. If this approach is taken, the risk would be reduced but not eliminated. This model now lists for $420, about $245 more than a base model.

Although these water heaters cost more than the standard or basic models, the higher prices are not due solely to the methods by which combustion air is drawn into the appliance. Theses higher-priced models also include features such as higher energy efficiency, longer warranties, and sediment prevention features that are not provided with the basic models. Based on the most recent information from the Directorate for Economic Analysis, the societal cost of these accidents, including, deaths, injuries, and property damage, may reach $395 million annually (TAB M). There are an estimated 40 to 50 million residential water heaters in use in the United States. Assuming a discount rate of 5 percent and an average useful life of 11 years, we estimate that a modification that eliminates nearly all of the incidents would be cost effective at $68 to $85 per unit.

5 Conclusions:

Based on this review of current and planned industry activities to address the hazard posed by gas-fired water heater ignition of flammable vapors, it appears that industry is now attempting to resolve this problem. A standards development project has begun, and industry is testing a new burner design to address the hazard. However, staff has concerns about the details and timely completion of these activities.

Although industry has orally briefed Commission staff on the design testing currently underway, they have not provided enough information to allow an independent assessment of the technology and its potential to resolve the vapor ignition problem. While industry representatives report that preliminary test results are favorable, additional testing must be performed to assure that the new technology does not cause other, currently unforeseen, hazards. No schedule is available for the completion of this work. Industry claims the testing will be completed soon and that as soon as the results of the additional testing have been reviewed by industry and a decision has been reached as to the design's viability, this information will be provided to CPSC staff.

The proposal for the standards development test activity being conducted under contract to the Gas Research Institute has been reviewed. Staff expressed reservations about the technical approach being taken to develop the test conditions for the test method. GRI and ADL responded by proposing a new test approach based on a "worst case" scenario. Staff believes that this approach, which presumes that the water heater will be exposed to a flammable vapor atmosphere and must be designed so that it does not produce ignition, is an adequate basis for a test method.

The current schedule for the test method development calls for the contract testing to be completed 9 months from contract award. GAMA estimates an additional 30 months to the effective date for the resulting ANSI standard provision. While CPSC staff will explore ways to accelerate the ANSI approval process, this may not be possible because of the major impact of a substantial change in design certification requirements. Also, schedules for test development can be delayed significantly because of technical difficulties in developing a method that produces consistent results.

Further testing needs to be done to validate the effectiveness of raising a water heater to eliminate or reduce ignition of flammable vapors if it is to be a solution to the vapor ignition problem. CPSC analysis of industry research shows that raising the water heater will greatly reduce the likelihood of vapor ignition in a room without air mixing. Further live fire testing must be conducted to ascertain the effects of room air mixing. Also, while it appears that temperature effects are minimal, the number of tests run is small, and additional testing would be necessary to quantify temperature effects. While industry states that the completed tests do not represent a "standards development activity," if industry were to use the results to define future standard test conditions, any bias in the test method may be reflected in the final test method.

The two ongoing industry activities, design testing and test method development, are independent. If the new technology proves effective in reducing the hazard, industry assures CPSC that it will be incorporated into all water heaters as quickly as possible. It is possible that products could be brought to market before the effective date of a voluntary standard. However, this does not obviate the need for a voluntary standard because other technologies may be developed as well, and a standard would be needed to evaluate them for acceptability.

Staff is convinced that gas-fired water heaters will continue to cause flammable vapor ignitions so long as the current "typical" water heater design is used. There are, however, several possible approaches to reduce this hazard by modifying the design of water heaters currently on the market. As discussed above, direct vent and water heaters with elevated combustion air intakes may hold promise as solutions.

Staff emphasizes that these are not proven solutions. They are approaches that may hold promise. Once modifications are completed, and if the modifications are successful in reducing the vapor ignition hazard, the appliances must still pass all other performance requirements currently required. Additionally, durability, service, and installation considerations must figure into the final acceptance of any design. Due to condensation during normal operation, water may accumulate in the combustion chamber. If this leads to corrosion and perforation of the combustion chamber, the vapor ignition protection could be lost. Also, water heaters need to be field serviced to re-light pilots or replace thermocouples. This means that the combustion chamber must be accessible to service personnel, but be able to be resealed to prevent vapors from entering. Clearly, significant changes will need to be made to assure long-term safe operation of any modified products.

Staff recommends that the Commission not issue an ANPR and work with industry to develop a voluntary standard. Industry has addressed the reasons for the previous recommendation to publish an advance notice of proposed rulemaking. At the November 22, 1994, industry meeting with Chairman Brown, industry stated that they are committed to developing a performance standard for new gas-fired water heaters to address the risk of death and injury from the ignition of flammable vapors. Industry is also is evaluating a new burner design to eliminate the ignition hazard. Industry has acknowledged by these actions that the solution to this problem is not solely a consumer education issue, but a water heater design issue as well.

If the Commission chooses this option, staff will alert the Commission immediately if progress on developing the performance standard is unsatisfactory and will brief the Commission on options to address the problem. This would include the option of issuing an ANPR, and initiation of the test method development work necessary to support rulemaking.

In view of the uncertainties in the content, timing and ultimate adoption of any industry voluntary standard, the staff believes very close participation with the industry is critical to judge the progress of standard development.

If the Commission directs the staff to publish an ANPR, it may not be possible to publish a proposed rule in one year. There are a number of difficult technical issues involved, and a test method can not, in all likelihood, be developed quickly. Because of the time required to develop the test method for a proposed rule, respond to issues raised by an ANPR, and support the preliminary findings required by the CPSA to propose a rule, the staff estimates that it may take as long as 18 months from publication of an ANPR to publication of a proposed rule.

If directed to publish an ANPR, the staff will try to accomplish the necessary work to support a proposed rule sooner than 18 months. However, any period for publication of a proposed rule that is longer than 12 months after ANPR publication, will require that the Commission, for good cause, extend the 12-month period for publishing a proposal as provided in section 9(c) of the CPSA.

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08#5595

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

VOTE SHEET

DATE: JUN 8 1994

TO : The Commission
Sadye E. Dunn, Secretary

FROM : Eric A. Rubel, General Counsel
Stephen Lemberg, Asst. General Counsel
Harleigh Ewell, Attorney, GCRA (Ext. 2217) HE

SUBJECT: Options for Gas-Fired Water Heaters Concerning Ignition of Flammable Vapors

This vote sheet concerns the staff's briefing package on options for Commission action to address the risk that gas-fired water heaters will ignite vapors from flammable liquids that are present in the home. Please indicate your vote on the following options.

I. ISSUE AN ADVANCE NOTICE OF PROPOSED RULEMAKING ("ANPR") (a draft ANPR is at Tab H of the briefing package). Please check the relevant option below.

____ 1. APPROVE THE DRAFT *FEDERAL REGISTER* NOTICE WITHOUT CHANGE.

____ 2. PUBLISH THE DRAFT *FEDERAL REGISTER* NOTICE WITH CHANGES (please specify).

____ 3. OTHER (please specify).

______________________________ (Signature)   ____________________ (Date)

II. DEFER TO THE VOLUNTARY STANDARDS PROCESS (staff will encourage ANSI and GAMA to develop adequate voluntary standards).

______________________________ (Signature)   ____________________ (Date)

NOTE: This document has not been reviewed or accepted by the Commission.
Init. SD Date 6/8/94

Products Identified Cleared 6/8/94 ... WITH GC MEMO REMOVED

OS 6/9/94

III. THE OFFICE OF COMPLIANCE AND ENFORCEMENT IS DIRECTED TO ANALYZE THE FEASIBILITY OF ACTION UNDER SECTION 15 OF THE CONSUMER PRODUCT SAFETY ACT.

_____ _____
(Signature) (Date)

IV. TAKE OTHER ACTION (please specify).

_____ _____
(Signature) (Date)

Comments/Instructions:

05#5595

OPTIONS PACKAGE
FOR
GAS-FIRED WATER HEATERS
AND
IGNITION OF FLAMMABLE VAPORS

For Further Information Contact:

Joseph Z. Fandey
Directorate for Engineering
(301)504-0508 ext. 1293

CPSA 6 (b)(1) Cleared
6/8/94 PR
No Mfrs/Prvtlbls or
Products Identified
WITH
GC MEMO
REMOVED

NOTE: This document has not been reviewed or accepted by the Commission.
Initial _____ Date 6/8/94

Executive Summary

This memorandum presents options to address the risk of death and injury associated with gas-fired water heaters igniting flammable vapors. Gas water heaters, of traditional design, draw the air necessary for combustion from the bottom. When they are mounted on the floor that means that they draw their air from near the floor. When gasoline or other heavier-than-air flammable vapors are present, the vapors tend to layer near or on the floor and can be pulled into the flame, be ignited and cause fires.

Each year an estimated 1,961 such fires occur causing an estimated 316 injuries, 17 deaths and $26 million in property damage, representing an annual estimated societal cost of $344 million. The typical injury happens when a person is using gasoline for cleaning purposes or when gasoline is accidentally spilled in an area close to a gas water heater.

Two years ago, staff requested the American National Standards Institute (ANSI) Accredited Z-21 sub-committee on water heaters to begin development of a performance standard to reduce the risk of death and injury presented by water heaters igniting flammable vapors. Since that time the water heater industry, through their trade organization, the Gas Appliance Manufacturers Association (GAMA), has funded two studies and a consumer information program but has not moved toward developing a standard. The voluntary standards process has been delayed while these studies were in process and no progress is known to staff towards developing an adequate standard.

Staff has demonstrated that the flammable-vapor-ignition fires associated with water heaters can be virtually eliminated using simple engineering principles about relative vapor densities of air and gasoline and the ability of mechanical barriers to change fluid flow patterns. Staff believes that these principles can be applied to new water heaters with little difficulty or cost.

Options available to the Commission to address this hazard include:

1. Issue an advance notice of proposed rulemaking to develop a performance standard to reduce or eliminate the risk of death or injury from the ignition of flammable vapors.
2. Defer to the voluntary standards process.
3. Pursue action under section 15 of the CPSA.

Staff recommends option 1, that the Commission publish an advance notice of proposed rulemaking to develop performance requirements for new gas-fired water heaters to address the risk of death and injury from the ignition of flammable vapors.

TABLE OF CONTENTS

05#5595

United States

CONSUMER PRODUCT SAFETY COMMISSION

Washington, D.C. 20207

MEMORANDUM DATE: JUN 8 1994

TO : The Commission
: Sadye E. Dunn, Secretary

THROUGH : Eric A. Rubel, General Counsel SF for EAR
: Bert Cottine, Executive Director

FROM : Ronald L. Medford, Acting Assistant Executive Director RLM for Hazard Identification and Reduction
: Joseph Fandey, Project Manager for Fire and Gas Voluntary Standards, ESEE (504-0508 ext. 1293)

SUBJECT : Options Paper re: Hazards associated with gas-fired water heaters igniting flammable vapors.

Purpose: To present options for the reduction of flammable vapor ignition hazards and resulting injuries and deaths.

Background:

Staff has been concerned with gas-fired water heaters igniting flammable vapors for several years. Deaths and injuries occur when flammable vapors, most often from spilled gasoline, are pulled into the water heater flame. Water heaters, of traditional design, draw air necessary for combustion from the bottom. When gasoline or other heavier-than-air flammable vapors are present they tend to layer near or on the floor and can be pulled into the flame where they can be ignited and cause fires.

Until the spring of 1991 staff had considered that the solution was one of changing consumer behavior to cause consumers to not use or store gasoline or other flammable vapors in the house.

In the spring of 1991 this approach changed when the staff realized that a mechanical fix (bringing combustion air into the appliance from 18 inches above the floor) could reduce or eliminate the risk of injury associated with water heater ignition of flammable vapors. The

NOTE: This document has not been reviewed or accepted by the Commission.
Initial SJ Date 6/8/94

CPSA 6(b)(1) Cleared 6/8/94 [illegible]
No Mfrs/Prvtlbrs or Products Identified
with 6C MEMO REMOVED.

information that changed the staff's approach was presented to the American National Standards Institute (ANSI) Z-21 Accredited Water Heater Subcommittee in November 1991. In March of 1992, staff formally requested that the ANSI subcommittee develop a performance standard designed to protect against flammable vapor ignition. (Tab A) The industry did not respond by undertaking standard development. Instead the Gas Appliance Manufacturers Association (GAMA) began to study the problem, ostensibly to determine whether there were geographic differences in injury rates. A study was also funded by GAMA to determine whether an 18 inch stand would prevent all ignitions of flammable vapors. When some fires were started, albeit in extreme conditions, the industry concluded that not all fires would be prevented and thereafter declined to consider elevating water heaters.

Instead of developing a product standard, as staff had requested, GAMA developed a consumer education program. The program is of excellent quality and the Commission has acknowledged this effort and voted to allow the use of the CPSC name and logo on certain publications and video tapes contained therein. However, the education program is not a "fix" for the problem, it is merely a means of informing consumers of the potential hazard.

Death and Injury Data:

CPSC Data:

The Directorate for Epidemiology presents 5-year fire, death, injury, and property damage averages for the period 1986-1991. (TAB B) Gas-fueled water heaters igniting flammable liquids are identified annually in only 20% of the 1,961 estimated annual fires associated with water heaters, but they account for 54% of the injuries (316), 44% of the of the deaths (17) and 30% of the property losses ($26,339,000).

Typical injury scenarios fell into three categories; children playing with or near gasoline, gasoline being used as a solvent, or other gasoline spill or leak.

Other Data:

GAMA sponsored work done by A.D. Little Laboratories (included in the supplemental materials available in the Office of the Secretary) examined several data bases including CPSC's and identified scenarios related to the bathroom, utility room, and a combination garage and

basement.

No current building code allows water heaters to be installed in bathrooms; nevertheless, many such installations exist. The two scenarios identified included people becoming "soaked" during activity such as cleaning parts, car repair or fueling operations. When such a person enters the bathroom where a water heater is installed, the vapors fall like water from the clothing and an ignition occurs. The other bathroom scenario involved children becoming covered in paint or a petroleum product and being brought into the bathroom and placed in the bathtub to have the material removed using gasoline as a solvent.

The utility room was associated with two scenarios. One, with a spill outside the room containing the water heater such as in an adjoining garage. The other scenario involved a spill within the room. In these accidents, some activity such as playing, fueling, or other use is often involved.

The garage and basement accidents again involve storage and associated spills, use of gasoline as a solvent, refueling and activities of children. The A.D. Little report indicates that of a data base of 135 incidents involving ignition of flammable vapors by residential gas water heaters, only 27 were known to have occurred in a garage. While 31 of the incidents did not specify the room location, the report's analysis showed that, in incidents where the room location was specified, the garage was involved in 10 of 27 deaths, 5 of 33 injuries and 2 of 11 incidents in which there were both deaths and injuries.

Applicable Codes and Standards:

Staff is aware of two standards which impact ignition of flammable vapors:

- The National Fuel Gas Code, NFPA 54/ANSI Z-223.1 which requires that water heaters installed in residential garages have all burners and burner ignition devices located not less than 18 inches above the floor. §5.1.9. In addition at §5.1.8 there is a requirement that "gas appliances shall not be installed in any location where flammable vapors are likely to be present, unless the design, operation, and installation are such to eliminate the probable ignition of the flammable vapors."

- The ANSI Gas Water Heater Standard, ANSI Z21.10.1 requires a label warning of the risk of injury associated with ignition of flammable vapors.

Staff has noted that the NFPA 54 requirements for garage installations have recently been incorporated into all model building codes. Staff notes that adoption by the model building codes does not guarantee that the provisions will be incorporated into local building ordinances, where compliance is enforced. Even if local jurisdictions adopt these provisions, garages apparently represent only a portion of the problem. Staff also notes that even if all new construction of houses and commercial replacements of existing residential water heaters followed the practice of elevating water heaters in the garage, there is a large portion of the incidents that would not be addressed. Staff believes that there has been very poor adherence over the years (since 1959) that the requirement has been in the National Fuel Gas Code. Moreover, staff believes that the provisions for other than garage installations are virtually never enforced for residential installations.

Additionally, the Division of Human Factors notes that the label is likely to have limited effectiveness and is unlikely to be thought about during activities unrelated to the water heater like lawn mower filling, or other gasoline usages such as for cleaning purposes, even if the label has been read.

Engineering:

Feasibility of a Performance Standard: Work at the Engineering Sciences Laboratory (ESEL) and at the American Gas Association Laboratory, by A.D. Little, demonstrated that when a gas water heater is installed on the floor, one half gallon of spilled gasoline caused dangerous levels of vapor in the area of the water heater burner. Engineering Laboratory work demonstrated that even minor elevation of the water heater (6 inches) significantly reduced the vapor levels reached. At the full 18 inch elevation, good protection was observed. The A.D. Little work also demonstrated greatly improved performance by elevation, but the work was extended to demonstrate that two gallons spilled with a lot of air turbulence forcing the vapors into the water heater could result in conditions where fires were possible.

Not every installation provides enough space above the water heater to allow elevation and proper venting for standard water heaters. To

address this problem, ESEL tested the water heaters on the floor with a 14 inch high sheet-metal barrier sealed to the floor. Even a one gallon spill 18 inches from the center-line of the water heater (so close that without the barrier, the gasoline ran under it) resulted in levels of flammable vapors below those considered unsafe. When these results were shared with the industry, the most important questions raised were about the effect of the barrier on the combustion characteristics of the water heater (to see whether unsafe levels of CO would be released). To answer this question, ESEL tested the water heater with and without the barrier. The results in combustion characteristics were indistinguishable. Staff believes that the combined work by CPSC and A.D. Little demonstrate that new water heaters can be made much safer. The effect of a barrier such as that used by ESEL can be built into a new water heater.

Feasibility of a Retrofit Method: Engineering has demonstrated the feasibility of developing a method to retrofit water heaters already installed in residences. (Tab C) The method used by Engineering was very simple, a piece of sheet metal (roof flashing) 14 inches by 6 feet was taped together using duct tape to form a circle slightly larger than the water heater's circumference and was then taped to the floor. This action forced all air for combustion to be drawn over the 14 inch barrier created. As a result, very little air was drawn from near the floor. This performance can also be incorporated into new water heaters without restricting design options. In order to assist in the retrofit work staff was undertaking, GAMA supplied water heaters which had been tested by the Department of Energy for fuel efficiency. Five water heaters were received at the ESEL and were properly fueled and run to determine the normal exhaust gas velocities that were produced at the top of each water heater. (Tab C) A "typical" water heater was then fitted with a small fan, which was adjusted to produce the same exhaust gas velocity and thereby safely simulate the gas flow which is produced by the burner's fire in normal operation. Using the fan instead of a burning unit allowed the tests to be conducted with gasoline while minimizing potential risk to laboratory personnel. The unit was transported to the National Institute of Science and Technology (NIST), where it was installed in a fire test facility with the fan used to simulate normal operation. Several experiments were conducted where gasoline was spilled on the floor near the water heater (18 inches from its center). Gasoline vapor concentrations in the air were measured at several locations,

most importantly at the burner. The results were that the barrier provided significant protection against flammable vapor ignition.

Industry Activities:

The staff's greatest concern is an apparent unwillingness on the part of the water heater manufacturers to take a serious look at the potential deficiencies (of taking combustion air from near the floor) in the current design of water heaters.

As noted above, the water heater manufacturers, through GAMA, have elected to emphasize consumer education over product improvements which could reduce or eliminate the risk of flammable vapor ignition. While staff believes that GAMA's efforts in the consumer education area are commendable, staff has repeatedly noted that it is not a complete solution. In the January 19, 1994 briefing package in which staff recommended that the Commission grant permission to GAMA to use the CPSC name and logo on certain consumer information materials, staff stated that "Staff considers that this [consumer information campaign] is an important and significant contribution to reducing the death and injury incidents which involve flammable vapors around the home. *However, staff believes that the program will be only partially effective unless combined with technical solutions*" [emphasis added]. (Tab D) The Division of Human Factors had voiced a similar concern regarding labeling. Human Factors stressed that prominent warning labels are necessary, but also noted that "A warning label is not an acceptable substitute..." (Tab E). The Chairman of the ANSI Z-21 Committee received a letter from Factory Mutual Research, and shared that letter with CPSC staff. (Tab F). Therein, Factory Mutual expressed the same concerns about the industry approach of only initiating a consumer information campaign. "If it is easy to handle the flammable liquid indoors, it will be done by some individuals, no matter how many warning labels or education programs to which they are exposed . . . Thus, the hazard [vapors in the home] cannot be eliminated. Therefore, it must be mitigated." Factory Mutual describes the approach taken by the industry as ". . . a public relations response to a technical hazard. Or as the computer-oriented would say, we are trying to solve a hardware problem with a software solution."

Economic Analysis:

Market Information: Based on Department of Energy data, the